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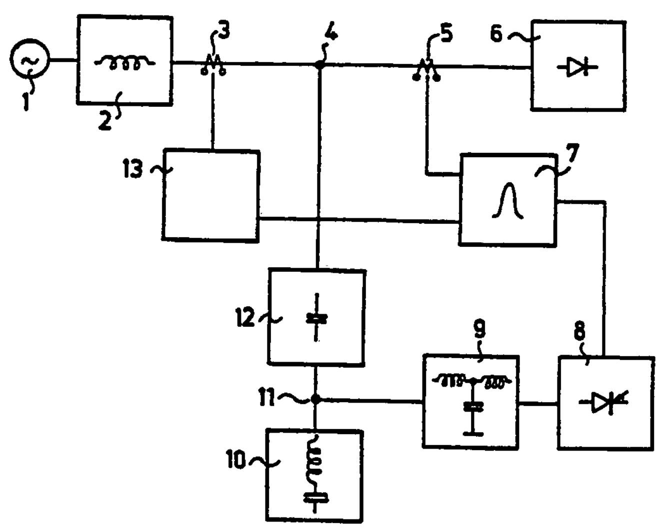

(57) Abstract

For realising the method of current injection an active filter arrangement for filtering harmonic current components generated by a nonlinear consumer connected to a power system is proposed, which comprises a harmonics source (8) for injecting current components of predetermined frequency into a bus bar (4) to be filtered, coupled with a regulating system (7), a supervising system (13), a low-pass filter (9), a series resonance circuit (10) tuned to a fundamental frequency determined for a power system and a coupling capacitance (12). The essence of the proposed filter arrangement lies in its further comprising a first current transformer (3) for measuring harmonic components of a current filtered and a second current transformer (5) for measuring harmonic components generated by a nonlinear consumer (6) to be filtered, the first and second current transformers (3, 5) being arranged by their respective primary terminals along the bus bar (4) to be filtered, wherein the first current transformer (3) is connected to the supervising system (13) and through this system to the regulating system (7), the regulating system (7) is coupled over an input with the current signal output of the second current transformer (5) and over an output connected to the harmonics source (8) with the low-pass filter (9) and via the latter with a common terminal (11) of the series resonance circuit (10) and the coupling capacitance (12), the coupling capacitance (12) being connected with a section of the bus bar (4) to be filtered, the section being arranged between the primary terminals of the first and second current transformers (3, 5).

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ACTIVE FILTER ARRANGEMENT FOR FILTERING HARMONIC CURRENT COMPONENTS GENERATED BY A NONLINEAR CONSUMER CONNECTED TO A POWER SYSTEM

BACKGROUND OF THE INVENTION

The invention refers to an active filter arrangement for filtering harmonic current components generated by a nonlinear consumer connected to a power system, which comprises a harmonics source for injecting current components of predetermined frequency into a bus bar to be filtered, coupled with a regulating system, a supervising system, a low-pass filter, a series resonance circuit tuned to a fundamental frequency determined for a power system and a coupling capacitance. The active filter arrangement proposed according to the invention can be the basis of pieces of high power equipment for filtering the harmonic current componnents generated by a nonlinear consumer and for compensating the reactive power noted at fundamental frequency of a power system.

In the present years the most commonly applied method of filtering harmonic current components generated by a nonlinear consumer is based on the principle of the passivity, wherein a series R-L-C resonance circuit tuned to a frequency value of a current component to be filtered is connected in parallel with the output of a nonlinear consumer, forming thereby low-impedance shunting current ways for the harmonic current components. The reactive power required by the nonlinear consumers is compensated in a designed amount by the tuned passive filtering means and this results in consuming leading current power at the fundamental frequency.

In the case of harmonic current components with quick alteration of their amplitude (e.g. the harminc current components produced by rectifying units of driving circuits in rolling equipment) the filtering effectivity of the passive filters deteriorates. Therefore it is common to apply wide-

-band passive filters. however, these filters are characterized by high loss level when compared to the narrow-band filters.

By means of passive filters practically it is impossible to filter the harmonic current components of variable frequency (such components occur e. g. in the asynchronous cascade drives, generated by the stators). A further problem linked with the application of the passive filters should be seen in the fact that the impedance characterizing the filters form together with the impedance of the network for power supply of the consumers forms parallel resonance circuit means which are capable of amplifying those of the harmonics with characteristic order, to which there is no passive filter tuned. In this way it is possible that in spite of filtering the voltage can be distorted in a distinctive manner on the noncharacteristic orders with lower amplitude present in the current but not undergoing filtering.

On applying passive filters it should be always taken into account that they receive a part of the distortion on harmonic frequencies being present in the network, therefore the filters should be overdimensioned in comparison to their designs applicable in case of taking into account the harmonic current components of the nonlinear consumer to be filtered by this filter.

The network resonance can not cause any problem, when a device for injecting a counterphase current into the network, which counterphase current shows as high amplitude as the current injected by the nonlinear consumer into the network. For the sake of economy it is desired to have a device not only injecting the current components, i.e. for harmonic filtering but consuming power of leading current at the fundamental frequency determined for the power system. The main advantage of an arrangement of the abovementioned kind would be the fact that it can filter the harmonic current components and partly or fully compensate the power of lagging

current at the nonlinear consumer. It would be also desired to have a device applicable in separation from the nonlinear consumer, and especially in an embodiment for harmonic filtering a higher number of nonlinear consumers. This embodiment should have a form installable also in an existing network, independently on the consumers settled working earlier or later.

There are known from the literature devices for diminishing the harmonic content of a current by injection respective components. The basic principle of actuating the devices of this kind is called active filtering method.

BACKGROUND ART

Ametani (in PROC. IEE, Vol. 119., No. 7., July 1972, pp. 857 to 864) shows a method of diminishing the harmonic content of the current of a nonlinear consumer, the proposed method based on injecting third harmonic of the current over the transformer applied for rectifying. The method proposed by Baird (in PROC. IEE, Vol. 166 (10), pp. 1730 to 1734) wishes to reach the same object by injecting the undulation of the rectified current into the transformer applied in the rectifying process. The main disadvantage shown by the above mentioned known methods is that they are applicable only for diminishing the harmonic content of the network current, but they are not capable of compensating the reactive power at a fundamental frequency determined for the power system. Moreover, they require rectifying transformers made by specific manufacturing methods. The drawbacks presented above result in the fact that these solutions can not find wide use.

Another method is based on the compensation of the flux (proposed by Sasaki in PAS, Vol. 90, No. 5., September/ /October 1971, pp. 2009 to 2019) by applying the harmonic current components on the alternating current side. For filtering the harmonics Sasaki makes use of a specially constructed four-winding transformer having a secondary winding for supplying the nonlinear consumer. There are two fur-

ther windings for injecting harmonic current components and for separating the fundamental frequency current from the current generator producing the harmonic components. In this method the main drawbacks strongly limiting its propagation are the specific transformator construction and the low effectivity. Because of the specific transformator construction the active filter for filtering the harmonic current components is very expensive when realised after the network has been settled to work (the transformators of the network should be replaced by the new ones, and the acoustic frequency amplifier applied for generating the harmonic current components shows from one side low effectiveness, and from other the disadvantage of consuming active power from the network, wherein the active power corresponds to the apparent power injected at the different harmonics and increased according to the effectiveness.

Another solution has become known under the name of Mohan's method (IEEE PES, Winter Meeting, New York, N.Y., January 30 to February 4, 1977: A 77026-8), wherein the existing passive filters are completed by means for injecting harmonic current components according to the order of the passive filters. The current injection is realised over the passive filters. This method ensures compensation of the negative influence of the filter's frequency drift on the filtering coefficience. For improving the efficiency of injecting the harmonic current components the method proposes the application of a parallel resonance circuit tuned to the frequency of the current component to be injected, and this parallel resonance circuit is arranged between the ground point of the system and the existing passive filter. A three-phase current generator for producing the harmonic components is proposed to be arranged connected to the common terminal of the existing filter and the parallel resonance circuit, whereby it is ensured that the existing filter connects the harmonic current generator

to the network.

The basic disadvantage of this method should be seen in the requirement of application passive filters, specific harmonic current generator for each of the harmonics and separate regulating units. The application of Mohan's method can be advantageous only in the case when rebuilding of the existing passive filtering means for a system of higher effectiveness is more expensive than the auxiliary application of active filtering. A further drawback lies in the fact that by this solution. it is impossible to avoid the network resonance and the other problems closely linked with the passive filters (e. g. the load by harmonic currents from other sources, the high oscillations occuring during filtering harmonic components of variable amplitudes).

SUMMARY OF THE INVENTION

The object of the invention is to provide a solution for filtering harmonic current components by means which are independent in their circuits on the nonlinear consumer(s) to be filtered. The proposed means should be connected to network in a manner that it is a consumer of the leading current power at a fundamental frequency determined for the network, thus compensating thereby (at least partly) the lagging current power taken up by the nonlinear consumer(s) to be filtered.

The invention is based on the principle of the active filtering requiring injecting the the network current components having the same amplitude as the components to be filtered but being generated in counterphase. It is a basic recognition of the invention that it is sufficient to apply only one harmonics source for generating the resulting harmonic current components filtered wherein the harmonics source is coupled with a regulating system for determining and controlling the generating process of the required harmonic components having the desired amplitude and phase according to the components to be filtered.

Hence, an active filter arrangement is proposed for filtering harmonic current components generated by a nonlinear consumer connected to a power system, comprising a harmonics source for injecting current components of predetermined frequency into a bus bar to be filtered, coupled with a regulating system, a supervising system, a low-pass filter, a series resonance circuit tuned to a fundamental frequency determined for a power system and a coupling capacitance, further comprising according to the invention a a first current transformer for measuring harmonic components of a current filtered and a second current transformer for measuring harmonic components generated by a nonlinear consumer to be filtered, the first and second current transformers being arranged by their respective primary terminals in the bus bar to be filtered, wherein the first current transformer is connected to the supervising system and through the latter to the regulating system being coupled over an input with the current signal output of the second current transformer and over an output connected to the harmonics source with the low-pass filter and via the latter with a common terminal of the series resonance circuit and the coupling capacitance, the coupling capacitance being connected with a section of the bus bar to be filtered, the section being arranged between the primary terminals of the first and second current transformers.

In an advantageous embodiment of the proposed active filter arrangement the low-pass filter comprises a series element including three inductance members, the first of them being connected to an output terminal of the harmonics source, the third of them being connected to the common terminal of the series resonance circuit and the coupling capacitance, the common point of the first and second of the inductance members is connected to a first terminal of a capacitance member, the common point of the second and third of the inductance members is connected to a first terminal of

of another capacitance member, wherein the capacitance members are connected by their respective another terminals to a line connecting an input terminal of the series resonance circuit tuned to the fundamental frequency of the power system with a neutral terminal constituting another output terminal of the harmonics source. The capacitance members of the proposed advantageous embodiment can be constituted either by condensers or by respective series members built up with parallel resonance circuits, the inductance members either by inductances or by respective parallel members of series resonance circuits, wherein the resonance circuits are tuned to the frequency values of the current components to be filtered.

It is proposed to apply a harmonics source consisting of a thyrystor inverter, a summator integrator, at least one comparator, at least two inverted signal amplifier and at least a first and a second monostable multivibrators controlled by pulse edge, wherein the output of the summator integrator is connected through the comparator to the inverted signal amplifiers and to the first monostable multivibrator controlled by pulse edge, the output of the first of the inverted signal amplifiers is connected to the input of the input of the summator integrator, the output of the second of the inverted signal amplifiers is coupled to the input of the second monostable multivibrator controlled by pulse edge, and the outputs of the first and second monostable multivibrators are connected with control terminals of the thyrystor inverter.

The active filter arrangement according to the invention works with especially high reliability when prepared with a regulating system comprising a band-pass filter tuned to the fundamental frequency of the power system, circuits for controlling amplitude and phase and a summator amplifier, wherein the band-pass filter is connected with the inputs of the circuits for controlling amplitude and phase,

the circuits for controlling are connected parallel to one another and their outputs are coupled with the summator amplifier. The circuits for controlling amplitude and phase can be realised e.g. by means of a band pass filter, a 90^0 phase inverter and units for regulating amplitude, wherein the output of the band-pass filter is connected directly and indirectly, through the 90^0 phase inverter to at least one of the units for regulating amplitude. The amplitude regulating units are built up either by an inverted signal amplifier and a potentiometer, wherein the input of the amplitude regulating unit is connected directly and through the inverted signal amplifier to the two end terminals of the potentiometer, the middle outlet of which is coupled with the output of the amplitude regulating unit, or by digital memory means connected to a control input and by a series member of a digital-analogue converter and a resistor arranged between the input and output of the amplitude regulating unit and connected through the converter with the digital memory means of the unit.

Hence, the invention proposes an active filter arrangement with a harmonics source, realised advantageously by a carrier frequency thyrystor of forced commutation and variable pulse width, a coupling capacitance connected to the power system to be filtered and a series resonance circuit tuned to the fundamental frequency of the power system, the common terminal of the coupling capacitance and the series resonance circuit being connected through a low-pass filter to the harmonics source. The low-pass filter ensures that the attenuation of the harmonic current components to be filtered by minimal and the network to be filtered receive minimal level carrier frequency current. This minimal level has to give minimal disturbing effects.

The proposed active filter arrangement selects, by means of the regulating system, the harmonic current components from the current of the nonlinear consumer(s) and rea-

the regulation of the width of the pulses generated by the harmonics source in a manner that the harmonic current components injected to the network through the coupling capacitance are in counterphase to the harmonic current components to be filtered from the current of the nonlinear consumer(s) and have the amplitude as high as the mentioned components have.

The supply network impedance and the network frequency are commonly subjected to changes resulting in varying the transfer coefficient of the open loop regulation depicted above and therefor a supervising system is applied for checking the content of harmonic components of the network current and the content detected is the basis of controlling the parameters of the regulating system in order to minimalize the level of the harmonic current components in filtered ranges.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described now in more detail by way of preferred embodiments when reference will be made to the accompanying drawings. In the drawings

Figure 1 shows the block diagram of the active filter arrangement proposed by the invention,

Figure 2 is a proposed embodiment of a low-pass filter applied according to the invention,

Figure 3a is a preferred embodiment of a series resonance circuit applied according to the invention,

Figure 3b is another preferred embodiment of a series resonance circuit applied according to the invention,

Figure 4 shows a preferred realisation of a low-pass filter applied according to the invention,

Figure 5 shows the circuit diagram of a proposed embodiment of a harmonics source to be applied in the active filter of the invention,

Figure 6 presents a preferred block diagram of a regulating system applied in the proposed active filter arran-

gement,

Figure 7a shows a possible embodiment of an amplitude regulating circuit applied in the regulating system of the active filter arrangement of the invention,

Figure 7b presents another proposed embodiment of an amplitude regulating circuit applied in the regulating system of the active filter arrangement of the invention, and

Figure 8 is a proposed block diagram of the supervising system applied in the active filter arrangement proposed by the invention.

DETAILLED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments shown in Figures 2, 3a, 3b and 4 are usually applied in one-phase supply networks, however, on the basis of information given below they can be applied without specific problems to three-phase networks.

The proposed active filter arrangement of the invention is shown divided into main blocks in Figure 1. A supply network 1 representing supply network impedance 2 is connected over primary terminals of a first and a second current transformer 3 and 5 to a nonlinear consumer 6. The primary terminals of the first and the second current transformers 3, 5 are arranged in a bus bar 4 to be filtered. The output of the first current transformer 3 is coupled with a supervising system 13, the output of the second current transformer 5 with a regulating system 7, the latter having an input coupled with the regulating system 13. The output of the regulating system 7 is connected with a harmonics source 8 and via the latter with a low-pass filter 9. The output of the low--pass filter 9 is connected to a common terminal 11 of a series resonance circuit tuned to a fundamental frequency of a power system and a coupling capacitance 12. The coupling capacitance is connected to the bus bar 4 to be filtered in its section lying between the first and second current transformers 3, 5.

The detailled description of the regulating system 7, harmonics source 8, low-pass filter 9, series resonance circuit 10 tuned to the fundamental frequency of the power system and the supervising system 13 will be given therebelow with connection with the respective Figures.

The active filter arrangement shown above with reference to Figure 1 operates as follows:

The second current transformer 5 carries out measurement of the current components generated by the nonlinear consumer 6. The output current signal of the second current transformer 5 is forwarded to the regulating system which regulates the content of harmonics in the output current of the harmonics source 8. The harmonic current components generated by the harmonics source 8 are transmitted to the common terminal 11 of the coupling capacitance 12 and the series oscillator circuit 10 tuned to the fundamental frequency. The current components generated in this way flow into the bus bar 4 to be filtered. The filtered current of the nonlinear consumer 6 is measured even by the first current transformer 3, the output current signal of which is the basic signal in the closed controlling and regulating loop constituted by the supervising system 13, the regulating system 7 and the connected units. This loop ensures minimal harmonic content in the output current of the harmonics source 8 in order to work again the changes of the voltage frequency and the impedance of the supply network 1.

According to the embodiment shown in circuit diagram of Figure 2 the high power part of the proposed active filter arrangement (without connections to the units for regulating and controlling) includes the low-pass filter 9, the series resonance circuit 10 tuned to the fundamental frequency and the coupling capacitance 12, the last two having a common terminal denoted by 11. According to the possibility of Figure 2, the low-pass filter 9 comprises a series element of three inductance members 9a, 9b, 9c and two parallel capaci-

three inductance members 9a, 9c, 9e and two parallel capacitance members 9b, 9d connected to the common points of the pairs of the inductance members 9a, 9c, 9e arranged in series. The three inductance members 9a, 9c, 9e together with the attached capacitance members 9b, 9d determine a two-stage low-pass filter, however, this arrangement is not compulsory: the number of the inductance members can be two or as high as desired. The number of the capacitance members is generally lower with one than the number of the inductance members in the low-pass filter 9.

The bus bar 4 to be filtered is connected with the coupling capacitance 12, more exactly, with a capacitance 12a being generally a condenser. The common terminal 11 is connected with an end terminal of a series member consisting of an inductance 10a and a capacitance 10b in the series resonance circuit 10 tuned to the fundamental frequency of the power system. The common terminal 11 is coupled on the other side with an end terminal of the inductance member 9e being the last in the series element of the low-pass filter 9. The other terminal of this inductance member 9e is connected to the common point of the second of the inductance members denoted by 9c and the capacitance member 9d. The second inductance member 9c, being the last but one in a longer series element is connected on the other side with a common point of the next, in this case the first inductance member 9a and the other capacitance member 9b. The inductance member 9a as the first one in the series element is connected with the terminal 8a of the harmonics source 8. The capacitance members 9b, 9d are with their other terminals connected to a line coupling the capacitance 10b with a neutral terminal 8b of the harmonics source 8.

In this arrangement the line between the common terminal 11 and the neutral terminal 8b works at fundamental frequency practically as a short-circuit because of the series resonance circuit 10 comprising the inductance 10a and the

capacitance 10b, whereby no network current of fundamental frequency flows into the harmonics source 8. The inductance members 9a, 9c, 9e and the capacitance members 9b, 9d forming the low-pass filter 9 do not allow the high-frequency current loops of the harmonics source 8 to be closed in the direction of the bus bar 4 to be filtered, and in the same time the harmonic current components to be filtered flow via the capacitance 12a into the bus bar 4 to be filtered, they are closed over the supply network impedance 2. The harmonic current components mentioned are characterised with the same amplitude as the harmonic current components to be filtered of the nonlinear consumer 6, they flow in counterphase, and the resultant of the filtered harmonic current components flowing through the supply network impedance 2 has zero or near zero value.

The harmonics source 8 can be made in form whether of a current generator or of a voltage generator. As shown in Figure 2, the inductance members 9a, 9c, 9e and the inductance members 9b, 9d can be made in form of inductances and capacitances.

The effectivity of filtering is generally determined by the filtering ratio expressing in the present circuit arrangement the quotient of the current component of given harmonic frequency flowing into the bus bar 4 to be filtered to the current of the same frequency leaving the harmonics source 8. The lower the filtering ratio the better the filtering arrangement, the effectivity of filtering. In the active filter arrangement of the invention the application of resonance circuits instead of the inductance members 9a, 9c, 9e and capacitance members 9b, 9d can be very advantageous for improving the filtering ratio.

Another possibility of improving the filtering ratio is to apply a modified series resonance circuit 10, for example as shown in Figures 3a and 3b.

A series resonance circuit consisting of an induc-

tance 101 and a capacitance 111 is inserted between the common terminal 11 and the neutral terminal 8b. Parallel to this series resonance circuit in three parallel lines there are arranged pairs of inductances denoted in Figure 3a by 102, 103, 104 and capacitances denoted in the same Figure by 112, 113, 114, wherein in each parallel line the common point of the inductance and the capacitance attached thereto is connected to one armature of the capacitance arranged in the next line, i.e. the common point of the inductance 101 and the capacitance 111 is connected to one armature of the capacitance 112, the other armature of which, as being the common point of this capacitance and the inductance 102 is coupled with one armature of the capacitance 113, wherein the other armature of the last is connected to one armature of the capacitance 114. The end terminals of the inductances 101, 102, 103, 104 are from one side connected to the capacitance 111, 112, 113, 114, respectively, and their other end terminals are connacted together to the common terminal 11 and the one armature of a capacitance 115, the other armature of which is coupled with the common point of the inductance 104 ând capacitance 114.

The circuit of Figure 3a arranged between the common terminal 11 and the neutral point 8b realises resonance conditions for the fundamental frequency current and parallel resonance conditions in the harmonic orders to be filtered. The number of the inductances denoted in this Figure by 101, 102, 103 and 104 is as high as the number of the harmonic components to be filtered. The same effect can be reached by a series member which comprises parallel resonance circuits inserted on the place of the inductance 10a, 0 whereby it is possible to realise the series resonance conditions at the fundamental frequency and the high impedance conditions at the frequency values of the harmonic current components to be filtered.

The circuit arrangement of Figure 3a, or the embodi-

described above and comprising the series member of parallel resonance circuits instead instead of the capacitance members 9b and 9d is a very advantageous solution in that case, when the harmonics source 8 should constitute a current generator. In this embodiment it is possible to have a circuit showing low output inpedance for the high frequency components, and shunt branches showing high impedance value at the harmonic orders to be filtered, hence, the full current of harmonic order to be filtered produced by the harmonics source 8 have a current way closed through the supply network impedance 2, whereby the circuit arrangement of the low-pass filter 9 is modified.

The harmonics source 8 in a voltage generator circuit arrangement is realised with a cirucit arrangement including the embodiment of Figure 3b having end terminals 120 and 130 inserted as the end points of the inductance members 9a, 9c, 9e of Figure 2.

The modified circuit arrangement for the replacement of the inductance members 9a, 9c, 9e of the low-pass filter 9 shown in Figure 2 will be described with reference to the Figure 3b.

Between the terminals 120 and 130 a series resonance circuit consisting of a capacitance 131 and an inductance 121 is included, wherein the common point of the mentioned capacitance 131 and inductance 121 is connected with an end terminal of an inductance 122 coupled over a common point with a capacitance 132, the common point being coupled with a further inductance 123 connected over another common terminal with a further capacitance 133. The mentioned common terminal is connected to a series member comprising an inductance 124 and a capacitance 134, wherein the connection is realised by the end terminal of the inductance 124. The armatures of the capacitances 131, 132, 133, 134 being not connected to the respective inductance 121, 122, 123, 124 are joined together and coupled with the terminal 130.

The similar effect can be ensured by inserting into the circuit arrangement of Figure 2 parallel members built up with series resonance circuits tuned to the frequency values characterizing the current components to be filtered, the parallel members replacing the inductance members 9a, 9c, 9e. In both embodiments it is realised the harmonic source 8 of voltage generator character is actuated at carrier frequency in idle running, and at the same time they have low load impedance at the harmonic frequency values of the components to be filtered.

The low-pass filter 9 realised by series and parallel resonance circuits is shown in Figure 4. In this proposed embodiment the inductance members 9a, 9c, 9d are replaced by four series resonance circuits tuned to the frequency values of the harmonic current components to be filtered, the four series resonance circuits are connected in parallel, and the capacitance members 9b, 9d are replaced by respective series members comprising four parallel resonance circuits tuned to the frequency values of the harmonic current components to be filtered. The series resonance circuits are denoted by 99e, 99f, 99g, 99h and the parallel resonance circuits by 99a, 99b, 99c and 99d.

An advantageous embodiment of the harmonics source 8 for application in the proposed active filter arrangement is shown in Figure 5. The object of the harmonics source 8 is to provide simultaneously all required harmonic components necessary for active filtering. The power range characterizing the circuit arrangements according to the invention excludes the application of linear amplifier means for the object mentioned, because of economic reasons, and this is the basis why a thyrystor inverter circuit is proposed, as it is usual in this power range. According to the invention it is, however, important that the thyrystor inverter is connected with a regulating circuit for ensuring that on the output of the thyrystor inverter all components be for-

warded which appear on the input of the regulating circuit and comprise the harmonic frequency current components to be filtered. In the harmonics source 8 an input is applied for forwarding control voltage U_v. This input is connected with an input of a summator amplifier 81, realised e.g. in an arrangement shown in the book of J. Markus entitled: Electronic Circuits Manual (McGraw-Hill, New York, 1971) and over the summator integrator 81 to an input of a comparator 82 with hysteresis. The comparator 82 is e. g. a Fairchild device of μAF356 type. The output of the comparator 82 is coupled through an inverted signal amplifier 83 in a feed-back connection with the summator integrator 81. The output of the inverted signal amplifier 83 is connected to another input of the comparator 82. The inverted signal amplifier can be the same type as the comparator. The output of the comparator 82 is connected also to a first monostable multivibrator 85 controlled by pulse edge and to an inverted signal amplifier 84. The output of the last is connected to a second monostable multivibrator 86 controlled by pulse edge. Both monostable multivibrators 85 and 86 can be e.g. the 74LS123 type of TEXAS and the are arranged before respective control inputs 87a, 87b of a thyrystor inverter of commonly known design. The output 87c of the thyrystor inverter 87 forwards the necessary harmonic current components.

This arrangement works according to the value of the control voltage U_v. At zero value of the control voltage U_v the output of the comparator 82 forwards a series of square wave signals with equal duty factor and frequency higher than the frequency of the harmonic current components to be filtered. The filtering conditions are set by a nonzero value of the control voltage. In this case square wave signals are generated with asymmetry corresponding to the alteration of the control voltage U_v. The asymmetry means, in the series of the generated square wave signals have diffe-

rent duty factors and spectrum comprising the frequency values present in the control voltage U_v. In the lines shown above in connection with Figure 5 the output of the comparator 82 is forwarded to the input control terminals 87a, 87b of the thyrystor inverter 87 whereby on the output 87c high power output signals can be obtained. The output signals comprise the harmonic signals present in the control voltage U_v and necessary for active filtering of the harmonic current components.

The output signal of the harmonics source 8 is forwarded through the low-pass filter 9, the series resonance circuit 10 tuned to the fundamental frequency and the coupling capacitance 12 to the bus bar 4 to be filtered. These elements together realise change of the amplitude dependent on the amplitude and the phase shift and therefore the active filtering of the harmonic current components can be effective only when the harmonics source 8 generates harmonic current or voltage having the same amplitude as the one measured by the second current transformer 5 after the alteration of phase and amplitude described above, but being in counterphase. To ensure this is the object of the regulating system 7 inserted between the second current transformer 5 and the harmonics source 8. The regulating system 7 renders it possible, to set the amplitude and phase of the signals received from the second current transformer 5 according to a required manner at each frequency to be filtered.

A possible embodiment of the regulating system 7 is shown in its circuit arrangement in Figure 6. The input of the regulating system is a band-pass filter 71 tuned to the fundamental frequency as accurately as possible. The output of the band-pass filter 71 is connected with a parallel arrangement of circuits 72 for controlling amplitude and phase. These circuits receive the output signal of the second current transformer 5 and each of them includes a band-

-pass filter 721 connected by two output series line to an summator amplifier 73 for forwarding the control voltage U_v to the harmonics source 8. The first of the afore-mentioned series line comprises a 90^0 phase inverter and an amplitude regulating unit 723, the second one includes only an amplitude regulating unit 723. The regulating units 723 in both series lines are coupled with the summator amplifier 73 by respective outputs 72a and 72b of the circuit 72.

The regulating system 7 as shown in Figure 6 works in the following way.

The current component of fundamental frequency constitutes the main part of current forwarded by the second current transformer 5 and this component is removed from the input signal of the regulating system 7 at the input by the band-pass filter 71. This filtering increases the accuracy of the further signal processing. The input band-pass filter 721 of the circuit 71 is tuned to the frequency of a preselected harmonic current component and it separates the signal to be regulated from the other signals constituting noise in the given circuit. The amplitude regulating units 723 realise amplifying the received signals according to a manual regulation or to signals received from the supervising system 13. The signals amplified in amplitude and taking into account the sign of the signal are added together by the summator amplifier generating the control voltage U_v required by the regulating system 7.

Some advantageous embodiments of the amplitude regulating unit 723 are shown in Figures 7a and 7b. In Figure 7a the unit for manual regulation is shown. An input signal 723i is forwarded to an end terminal of a potentiometer denoted by 723b directly and to the other end terminal via an inverted signal amplifier 723a. From the potentiometer 723b an output control signal can be received at an output 723o. The output signal can be regulated by the potentiometer applied denoted by 723b.

In Figure 7b an embodiment is presented, wherein the control is ensured by an outer control system, e.g. by the supervising system 13. The signal of the outer control system is generally a digital system and for this possibility the circuit is shown here. A digital control signal 723v generated e.g. by the supervising system 13 is received by digital memory means 723c, the output of which controls an input of a digital multiplier 723d. This element is a multiplier type digital analogue converter, with reference input connected to an input forwarding the input signal 723i. The output of the digital multiplier 723d is connected to a summing resistor 723e coupled with an output 723o of the amplitude regulating unit 723.

The band-pass filter 71 tuned to the fundamental frequency of the power system, the band-pass filter 721 and the 90^{0} phase inverter are per se well-known circuit parts, which can be realised e.g. on the basis of the information given in the afore-mentioned book of J. Markus entitled "Electronic Circuits Manual". The same can be related to the inverted signal amplifier 723a, which is generally an integrated circuit of μAF 356 type (product of FAIRCHILD). The digital memory means 723c is e.g. a TEXAS product, 74LS373 type, and the digital multiplier 723d an ANALOG DEVICES element of AD7523 type.

A proposed embodiment of the supervising system 13 is illustrated in Figure 8. This is a feed-back system realised with the first current transformer 3, therewith there are band-pass filters 13a are connected in a parallel arrangement. The band-pass filters 13a are tuned to the frequency values of the harmonic current components to be filtered. The outputs of the band-pass filters 13a are coupled with a multichannel analogue-digital converter realised e.g. with an integrated circuit ANALOG DEVICES type AD 7581, and thereby with a microprocessor unit 13c for regulating. The microprocessor unit 13c connected to the respective am-

plitude regulating units 723 requiring signals automatically generated for regulating processes the signals forwarded by the multichannel analogue-digital converter 13b measuring thereby the harmonic content of the output current of the nonlinear consumer 6. The harmonic .content determined in this way is the basis of regulation given by the microprocessor unit 13c ensured as long as the harmonic content of the output current reaches to required minimal level.

The active filter arrangement built up according to the invention in a circuit arrangement shown in Figure 1 is a very effective solution for filtering the harmonic current components generated by a nonlinear consumer, wherein it is possible to follow the frequency changes occuring in the power system.

CLAIMS:

1. An active filter arrangement for filtering harmonic current components generated by a nonlinear consumer connected to a power system, comprising a harmonics source (8) for injecting current components of predetermined frequency into a bus bar (4) to be filtered, coupled with a regulating system (7), a supervising system (13), a low-pass filter (9), a series resonance circuit (10) tuned to a fundamental frequency determined for a power system and a coupling capacitance (12), characterized in further comprising a first current transformer (3) for measuring harmonic components of a current filtered and a second current transformer (5) for measuring harmonic components generated by a nonlinear consumer (6) to be filtered, the first and second current transformers (3, 5) being arranged by their respective primary terminals in the bus bar (4) to be filtered, wherein the first current transformer (3) is connected to the supervising system (13) and through the latter to the regulating system (7), the regulating system (7) is coupled over an input with the current signal output of the second current transformer (5) and over an output connected to the harmonics source (8) with the low-pass filter (9) and via the latter with a common terminal (11) of the series resonance circuit (10) and the coupling capacitance (12), the coupling capacitance (12) being connected with a section of the bus bar (4) to be filtered, the section being arranged between the primary terminals of the first and second current transformers (3, 5).

2. The active filter arrangement according to claim 1, characterized in that the low-pass filter (9) comprises a series element including three inductance members (9a, 9c, 9e), the first of them (9a) being connected to an output terminal (8a) of the harmonics source (8), the third of them (9e) being connected to the common terminal (11) of the series resonance circuit (10) and the coupling

capacitance (12), the common point of the first and second of the inductance members (9a, 9c) is connected to a first terminal of a capacitance member (9b), the common point of the second and third of the inductance members (9c, 9e) is connected to a first terminal of another capacitance member (9d), the capacitance members (9c, 9e) being connected by respective another terminals to a line connecting an input terminal of the series resonance circuit (10) tuned to the fundamental frequency of the power system with a neutral terminal (8b) constituting another output terminal of the harmonics source (8), wherein the inductance members (9a, 9b, 9c) are made in form of inductances and the capacitance members (9b, 9d) in form of condensers.

3. The active filter arrangement according to claim 1, **c h a r a c t e r i z e d i n t h a t** the low-pass filter (9) comprises a series element including three inductance members (9a, 9c, 9e), the first of them (9a) being connected to an output terminal (8a) of the harmonics source (8), the third of them (9e) being connected to the common terminal (11) of the series resonance circuit (10) and the coupling capacitance (12), the common point of the first and second of the inductance members (9a, 9c) is connected to a first terminal of a capacitance member (9b), the common point of the second and third of the inductance members (9c, 9e) is connected to a first terminal of another capacitance member (9d), the capacitance members (9c, 9e) being connected by respective another terminals to a line connecting an input terminal of the series resonance circuit (10) tuned to the fundamental frequency of the power system with a neutral terminal (8b) constituting another output terminal of the harmonics source (8), wherein at least one of the capacitance members (9b, 9d) is constituted by a series member of parallel resonance circuits (99a, 99b, 99c, 99d) tuned to the frequency values of the filtered current components.

4. The active filter arrangement according to any of claims 1 to 3, **c h a r a c t e r i z e d i n t h a t** the low-pass filter (9) comprises a series element including three

members (9a, 9c, 9e), the first of them (9a) being connected to an output terminal (8a) of the harmonics source (8), the third of them (9e) being connected to the common terminal (11) of the series resonance circuit (10) and the coupling capacitance (12), the common point of the first and second of the inductance members (9a, 9c) is connected to a first terminal of a capacitance member (9b), the common point of the second and third of the inductance members (9c, 9e) is connected to a first terminal of another capacitance member (9d), the capacitance members (9c, 9e) being connected by respective another terminals to a line connecting an input terminal of the series resonance circuit (10) tuned to the fundamental frequency of the power system with a neutral terminal (8b) constituting another output terminal of the harmonics source (8), wherein at least one of the inductance members (9a, 9b, 9c) is constituted by a parallel member of series resonance circuits (99e, 99f, 99g, 99h) tuned to the frequency values of the current components to be filtered.

5. The active filter arrangement according to any of claims 1 to 4, c h a r a c t e r i z e d i n t h a t the harmonics source (8) consists of a thyrystor inverter (87), a summator integrator (81), at least one comparator (82), at least two inverted signal amplifiers (83, 84) and at least a first and second monostable multivibrators controlled by pulse edge (85, 86), wherein the output of the summator integrator (81) is connected through the comparator (82) to the inverted signal amplifiers (83, 84) and to the first monostable multivibrator (85) controlled by pulse edge, the output of the first of the inverted signal amplifiers (83) is connected to the input of the summator integrator (81), the output of the second of the inverted signal amplifiers (84) is coupled to the input of the second monostable multivibrator (86) controlled by pulse edge, and the outputs of the first and second monostable multivibrators (85, 86) are connected with control terminals (87a, 87b) of the thyrystor inverter (87).

6. The active filter arrangement according to any of claims 1 to 5, characterized in that the regulating system (7) comprises a band-pass filter (71) tuned to the fundamental frequency of the power system, circuits (72) for controlling amplitude and phase and a summator amplifier (73), wherein the band-pass filter (71) tuned to the fundamental frequency is connected with the input of the circuits (72) for controlling amplitude and phase, the circuits (72) are connected parallel to one another and their outputs (72a, 72b) are connected to the summator amplifier (73).

7. The active filter arrangement according to claim 6, characterized in that each circuit (72) for controlling amplitude and phase includes a band-pass filter (721), a 90^0 phase inverter (722) and amplitude regulating units (723), wherein the output of the band-pass filter (721) is connected via the 90^0 phase inverter (722) and directly to the amplitude regulating unit (723).

8. The active filter arrangement according to claim 7, characterized in that the input (723i) of the amplitude regulating unit (723) is connected directly and through an inverted signal amplifier (723a) to two end terminals of a potentiometer (723b) having a middle outlet, wherein the middle outlet of the potentiometer (723b) is connected to an output (723o) of the amplitude regulating unit (723).

9. The active filter arrangement according to claim 7, characterized in that the input (723i) of the amplitude regulating unit (723) is connected through a digital-analogue converter (723d) of multiplier type and a resistor (723e) to the output (723o), wherein digital control means of the digital-analogue converter (723d) is linked with a control input (723v) of the amplitude regulating unit (723) over digital memory means (723c).

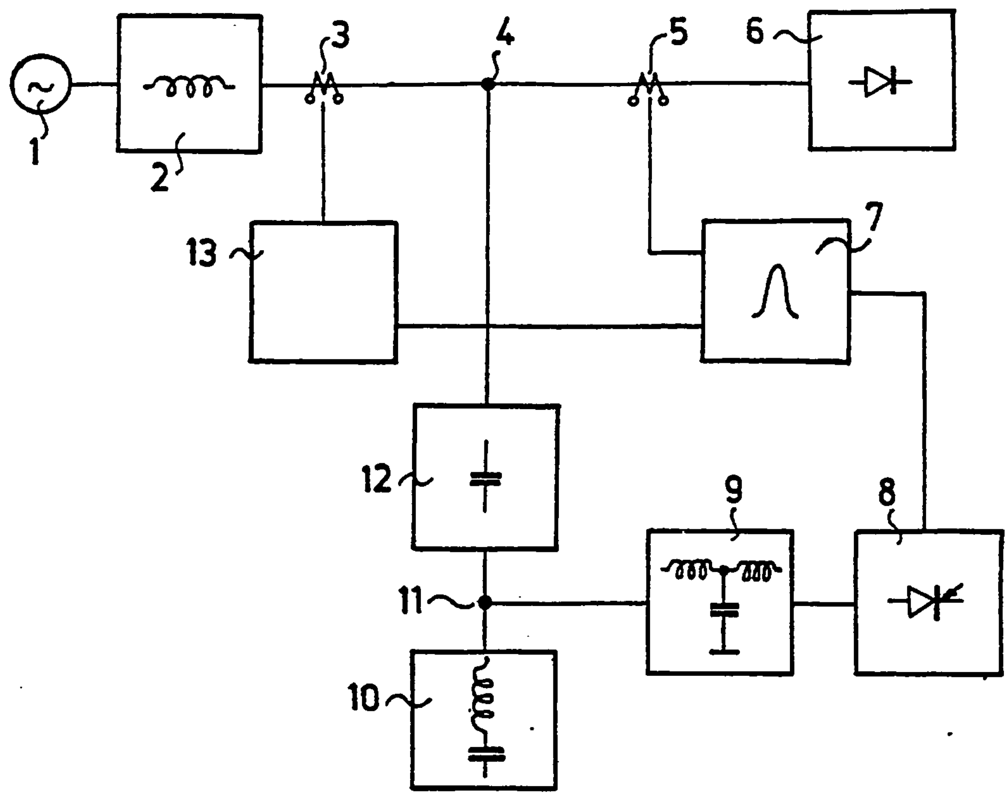


Fig.1

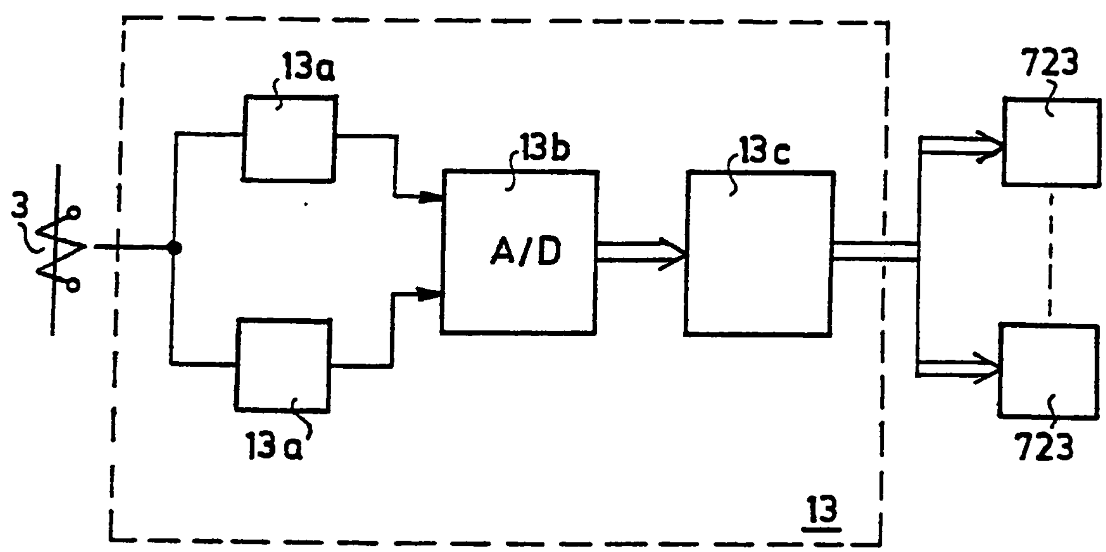


Fig.8

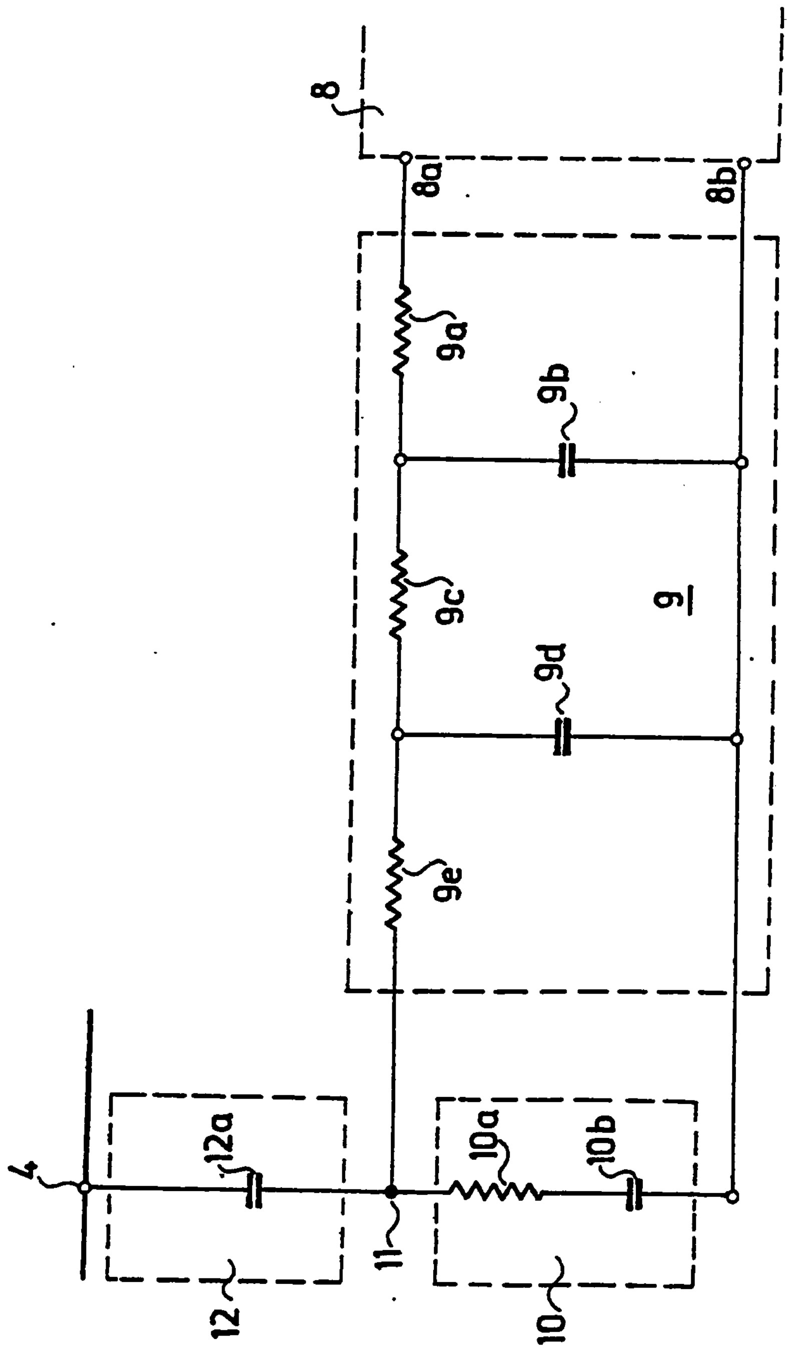
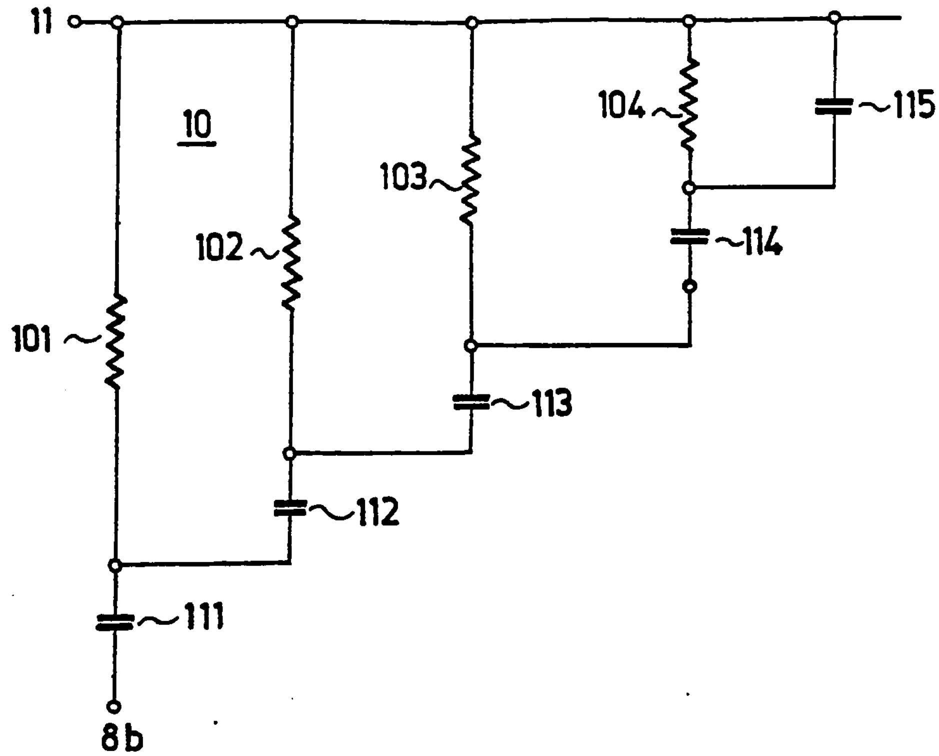


Fig. 2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115
8b

Fig. 3 a

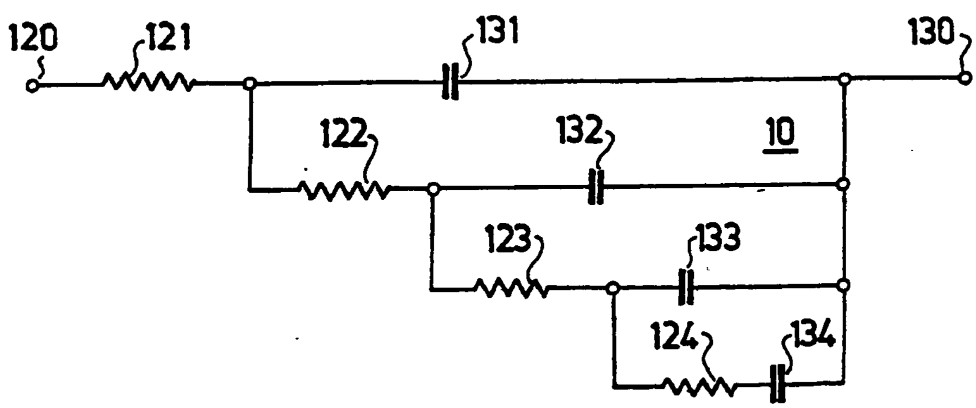
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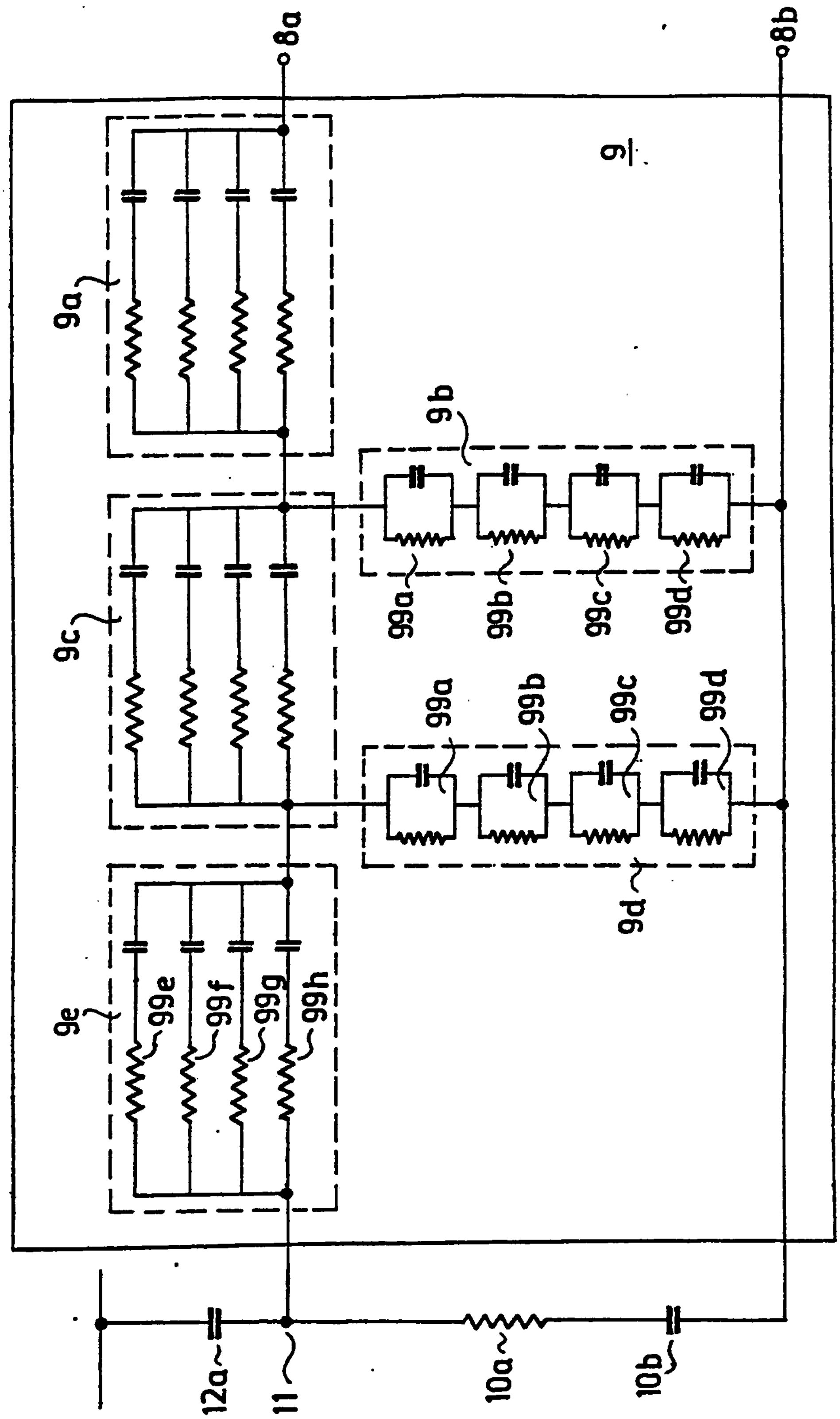
Fig.3 b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99f
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99h
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11
10a
10b

Fig. 4

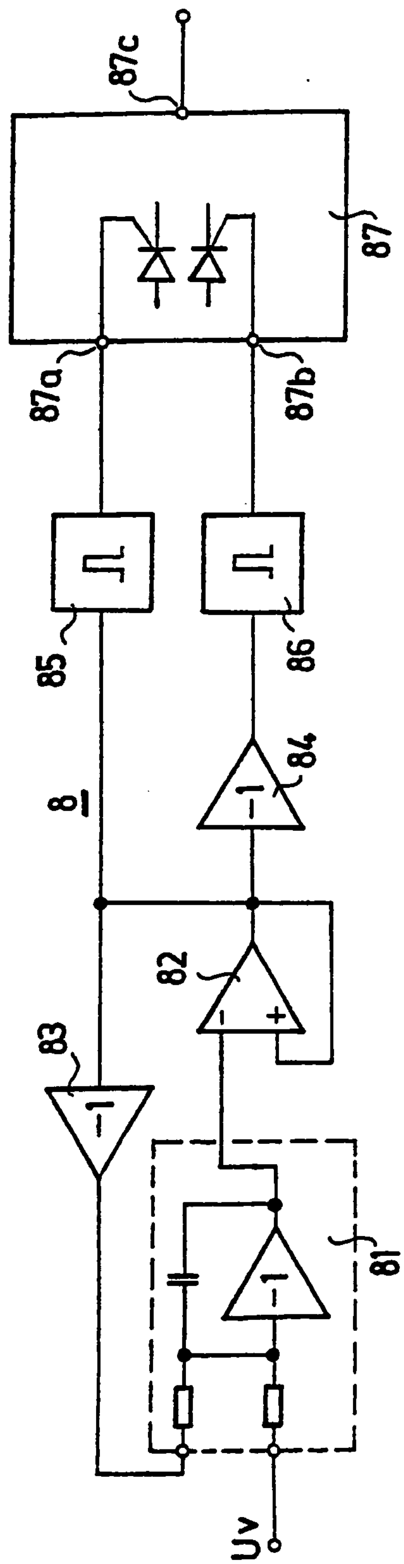

Fig.5

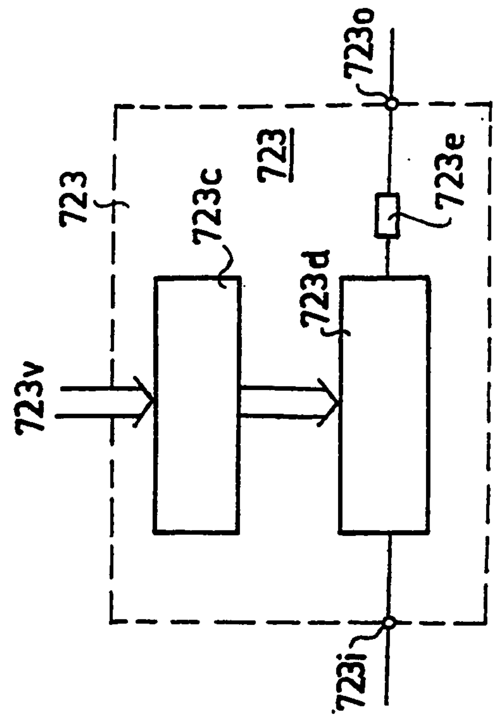

Fig.7b

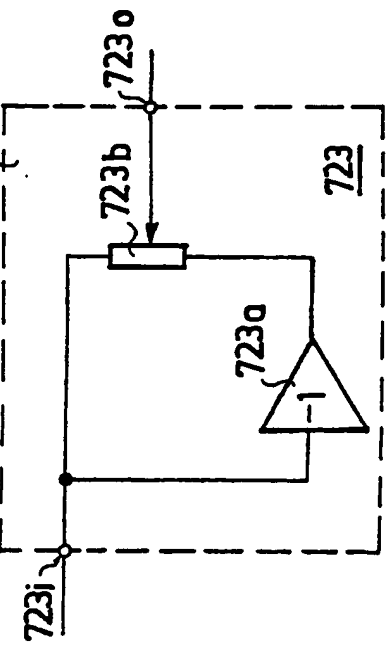

Fig.7a

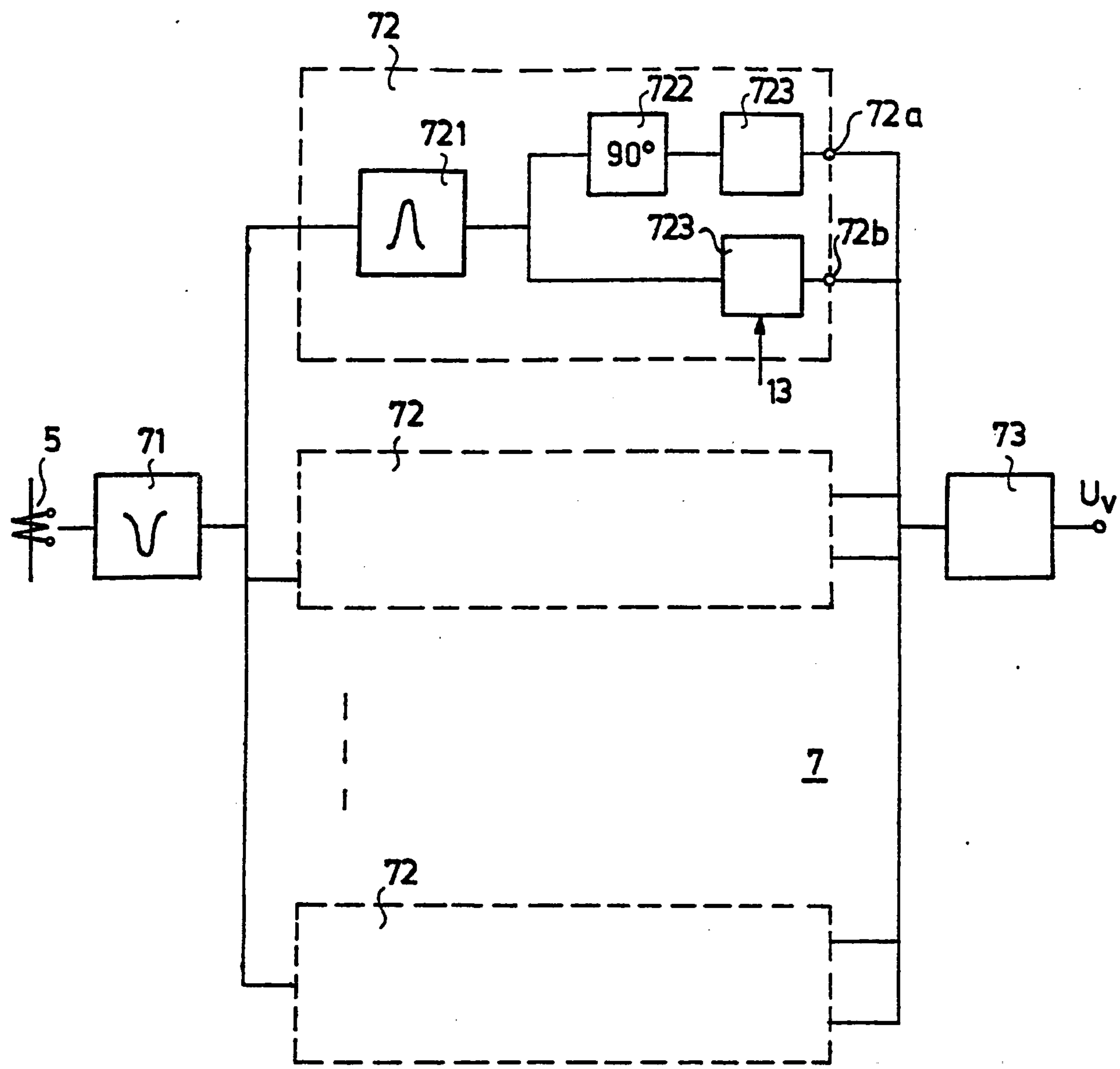

Fig.6

INTERNATIONAL SEARCH REPORT

International Application No PCT/HU 88/00062

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: H 03 H 11/00

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
$Int.Cl.^4$:	H 03 H 5/00, 7/00, 11/00; H 02 M 1/00.

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

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III. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	IEEE Transactions on Power Apparatus and Systems, Volume PAS-90, no. 5, issued 1971 September/October, H. Sasaki, "A new method to eliminate AC Harmonic Current by magnetic flux Compensation-Considerations on Basic Design", see totality; especially pages 2009-2019.	(1-9)
A	Proceedings of the Institution of Electrical Engineers, Volume 119, no. 7, issued 1972 July, A. Ametani, "Generalised method of harmonic reduction in A.C - D.C Convertors by harmonic current injection", see totality; especially pages 857-864.	(1-9)
A	IEEE Power Engineering Society, Text of "A" Papers from the Winter Meeting, issued 1977 January 30 - February 4 (New York), N. Mohan, "Active Filters for AC Harmonic Suppression", see totality; especially pages 1-7.	(1-9)

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* Special categories of cited documents:

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20 December 1988 (20.12.88)	22 December 1988 (22.12.88)
International Searching Authority	**Signature of Authorized Officer**
AUSTRIAN PATENT OFFICE	[illegible signature]

Form PCT/ISA/210 (second sheet) (January 1985)